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BULLETIN
OF THE
AMERICAN GEOGRAPHICAL SOCIETY.

Vol. XXXI **1899.** **No. 4**

PHYSICAL GEOGRAPHY OF NEW YORK STATE.

BY

RALPH S. TARR.

PART VIII.—THE GREAT LAKES AND NIAGARA (*Continued*).

NIAGARA.

DESCRIPTION.*—The Niagara River emerges from Lake Erie, near Buffalo, a full-born river, and in its course to Lake Ontario, a distance of about 30 miles, it receives only slight additions to its supply of water, mainly from the small Tonawanda and Chippewa Creeks. It is unlike most rivers also in the fact that it is essentially free from sediment load. The river leaves Erie as filtered

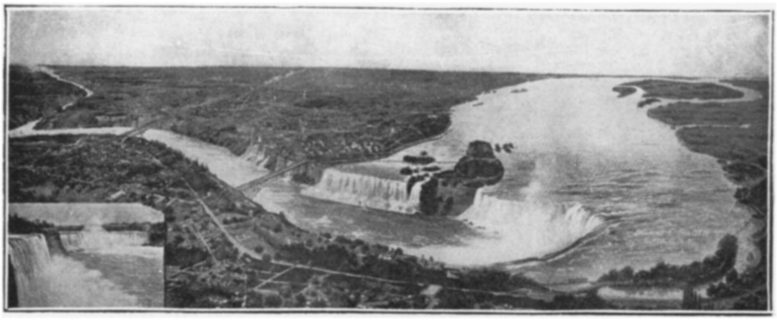
FIG. 1.—A BIRD'S-EYE VIEW OF NIAGARA RIVER SHOWING THE BROAD, QUIET UPPER COURSE, THE CATARACT AND THE GORGE BELOW.

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* See Capt. Basil Hall, Travels in North America, Vol. I, Edinburgh, 1829, 177–208; Gilbert, Sixth Ann. Rept. Niagara Reservation Commission, 1890, 61–84; Physiography of United States, American Book Co., N. Y., 1896, 203–236.

water; and, thus robbed of cutting tools, under normal conditions would be able to perform little work of valley formation. It would be able to act chemically, but could do almost no mechanical work, notwithstanding its immense volume.*

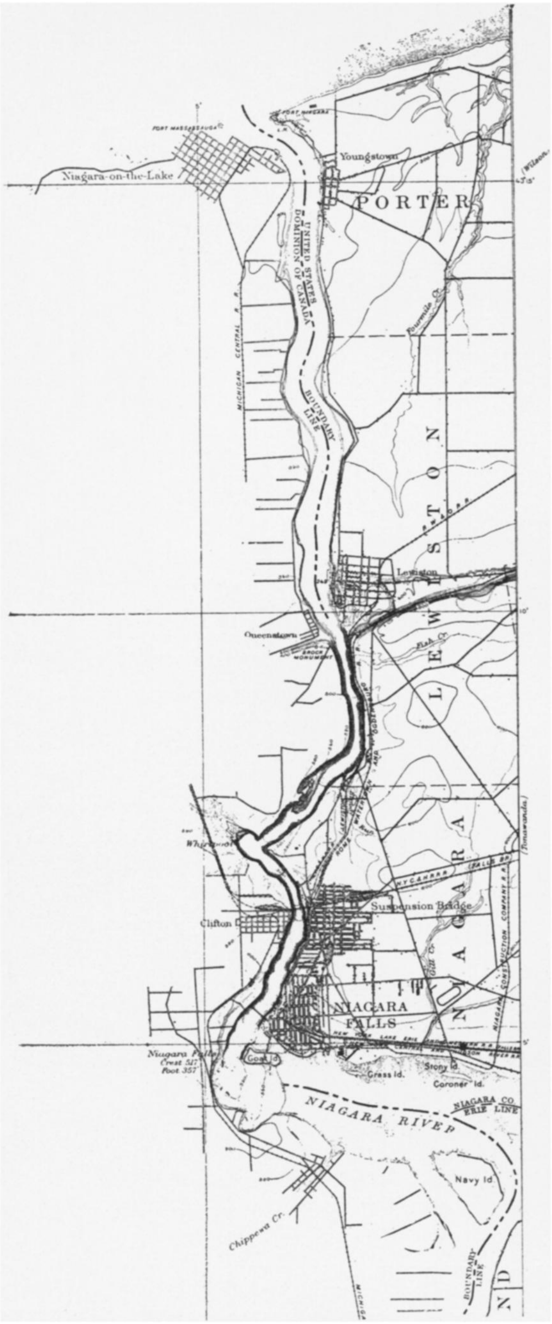

FIG. 2.—A PORTION OF THE U. S. GEOLOGICAL SURVEY CONTOUR MAP OF NIAGARA, SHOWING THE TWO PLAINS AND THE ESCARPMENT AT LEWISTON.

As has been shown in an earlier article,† and as is evident from the accompanying map (Figs. 2 and 5), the region between Lakes Erie and Ontario consists of two plains, divided by an escarpment about 200 feet high. The upper plain passes beneath Lake Erie, the lower beneath Lake Ontario, where it is faced by a sublacustrine escarpment. The escarpment separating the upper and lower plains is steeply sloping and is underlaid by the very massive Niagara limestone, which forms the surface rock of the upper plain to a point a short distance above the crest of the cataract (Fig. 3). This Niagara limestone has a total thickness of about 140 feet, but is only about 20 feet thick at the escarpment, because its upper layers have been removed by denudation. At the Falls (Fig. 14), the limestone is from 60 to 80 feet thick. Beneath this are shales and sandy layers, all bedded as nearly horizontal sheets, dipping gently southward toward Lake Erie at the rate of about 35 feet per mile. The rock above the Niagara, and underlying the Erie plain, consists of the Salina shales; and near Buffalo there is another bed of limestone, the Corniferous.

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*Blackwell, Amer. Journ. Sci., 1844, XLVI, p. 67, estimates the volume of Niagara to be 22,440,000 cubic feet, or 1,402,500,000 pounds per minute.

†Tarr, Bull. Amer. Geog. Soc., XXVIII, 1896, 107.

The Niagara River crosses this section from Erie to Ontario, commencing as a broad river, with gentle course excepting where it crosses the Corniferous limestone, at which place the current becomes rapid. For fifteen miles it flows almost on the surface of the plain, at one place even dividing into two channels with the large Grand Island between. Without cutting tools the river has not been able to carve a noticeable valley. Then, about a half or three-quarters of a mile above the Falls, the current quickens (Fig. 16) and soon the river becomes transformed to "a broad, roaring rapid, tumbling over one ledge after another with tumultuous haste." *

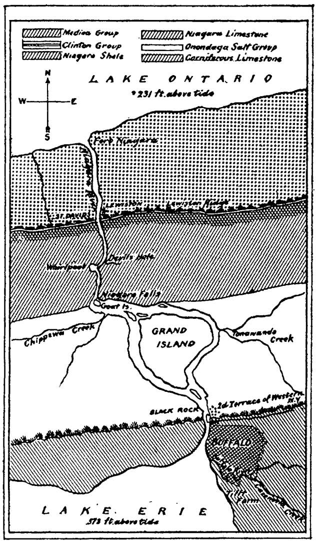

FIG. 3.—GEOLOGICAL MAP OF VICINITY OF NIAGARA (AFTER GILBERT).

The water then tumbles over the brink of the Falls (Fig. 10) from a height of 517 feet above sea-level down to the level of 357 feet, giving a fall of about 160 feet. † Above the upper rapids the river is broad, and the depth from 10 to 22 feet. At the cataract it is divided by Goat Island into two falls (Fig. 7), the smaller being the American, the larger the Canadian or Horseshoe, over which the bulk of the water flows, with a depth, according to Schermer-

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* Gilbert, Physiography of United States, New York, 1896, p. 208.

† Schermerhorn (Amer. Journ. Sci., CXXXIII, 1887, 278–284) states that the fall is 155 feet high on the Canadian side, 161 feet near Terrapin Tower, and 169 feet near the eastern side of the American Falls.

horn, probably averaging less than 4 feet, though without doubt reaching 20 feet at the apex.

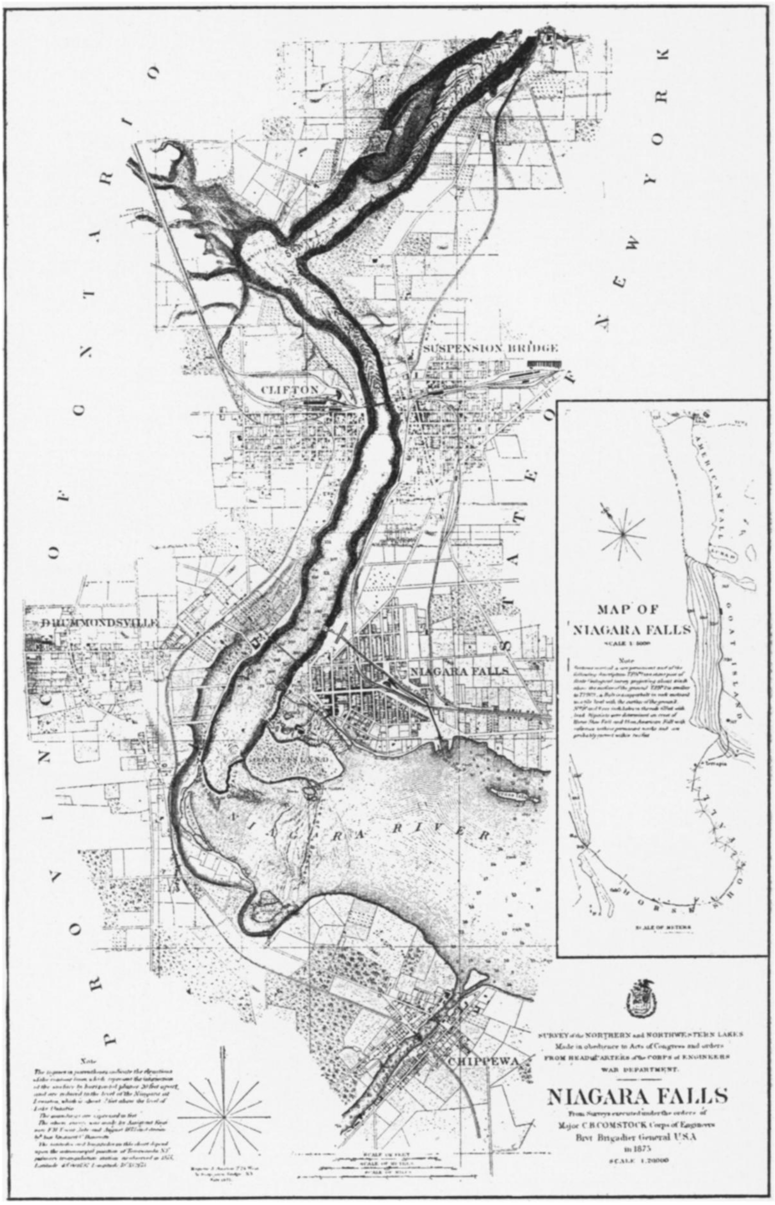

FIG. 4.—MAP OF NIAGARA FALLS AND VICINITY.

From the base of the Falls, for a distance of about seven miles, the river occupies a deep channel cut through the Niagara limestone into the underlying shale, limestone and sandstone beds, to the depth of 200 or 300 feet, and with a width commonly between 200 and 300 yards. Throughout its distance, excepting in one place, the gorge walls are capped by the massive Niagara limestone, while beneath this are beds of shale with one or two strata of harder rock. Near the base of the cliff is a talus (Figs. 18, 19 and 21) in which numerous large boulders of the Niagara limestone form a prominent part, having fallen there from the cap rock of the gorge walls.* From the Falls nearly down to the railway bridges, the gorge is broad and the water fairly quiet, excepting near the Falls, where the river swirls around under the disturbance of the tremendous vertical descent at the cataract. In this stretch of quiet water the soundings reveal a depth in one place of 189 feet, and in several other places of 160 feet (Fig. 4).

Near the railway bridge the gorge narrows quite abruptly, and the current quickens until it is transformed to a furious mass of whirling water, forming the Whirlpool Rapids (Fig. 17). In the bed of this there are apparently large blocks of the Niagara limestone, which throw the river surface into great billows. Here the river depth is evidently shallow.

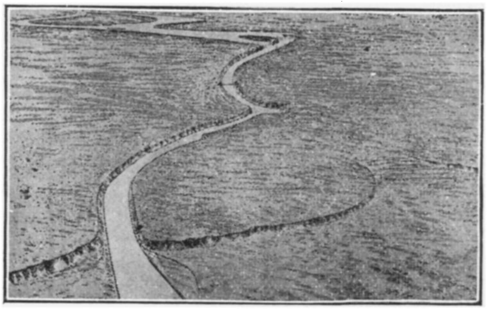

FIG. 5.—THE TWO PLAINS AND ESCARPMENT, WITH THE WHIRLPOOL—ST. DAVID'S CHANNEL ON THE RIGHT (AFTER GILBERT).

Below this the gorge broadens out again and forms a great elbow, known as the Whirlpool (Figs. 4, 5, 6 and 20), where the water is again deep. At this place the gorge turns nearly at right angles, narrowing and broadening in one or two places, being especially narrow at Foster Flats. Throughout this lower half of the gorge the current is prevailingly rapid, and the depth evidently much less than that above the Whirlpool Rapids. Gilbert† makes the following estimate of the depth of the river at various places: At the Whirlpool Rapids, 35 feet; at the outlet of the Whirlpool, 50 feet;

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* These falls of limestone are often noticed; see, for instance, Claypole, Nature, XXXIX, 1889, 367. A large fall also occurred in the Spring of 1899.

† Amer. Geologist, XVIII, 1896, 232–233.

opposite Wintergreen Flat, 35 feet; and below Foster Flat, 70 feet. The depth of the Whirlpool is estimated to be about 150 feet.

After a passage of about seven miles through the gorge (Figs. 18–21), alternately expanding and contracting, and with the current now moderate and now rapid, and in places even violently rapid, the river emerges from its cañon (Fig. 21) and passes peacefully across the lower plain, in a valley somewhat broader than the gorge, and bounded by low banks rising to the level of the lower plain.

Throughout its gorge the river is everywhere bounded by rock walls, excepting in one place, the Whirlpool, where, on the Canadian side, there is a drift-wall, with a slope much more gentle than commonly (Fig. 4), and down which a tiny stream passses into the Niagara. In line with this drift-filled depression, the rock-capped Queenstown escarpment itself is interrupted by a drift-wall near the village of St. David's (Fig. 6). There seems to be a buried valley here extending from the Whirlpool to St. David's. This is called the St. David's channel, and it has apparently had considerable influence upon the history of the Niagara River.

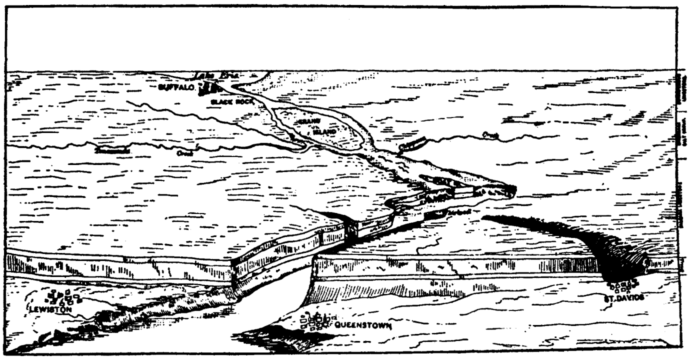

FIG. 6.—A BIRD'S-EYE VIEW OF NIAGARA (AFTER GILBERT).

While the river is not rapidly deepening its valley in the upper 15 miles, nor in most of its course below the cataract, it has long been evident that very active work of valley formation is in progress at the cataract itself. Since Niagara is a post-glacial stream, having had its birth at the time when the upper Great Lakes abandoned the Chicago outlet for the Mohawk,* it has seemed to many possible to use Niagara as a measure of this part of geological time. Much study has therefore been given to the Niagara River. The gorge has evidently been *formed* by the river itself, and the rate of present wear is known; but the problem proves more complex as studies are extended. Perhaps the best way of treating the subject clearly, and with a measure of completeness, is to consider first of all the contributions of the principal students of the problem, and then to discuss some of the results.

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* See previous article in this series, Bull. Amer. Geog. Soc., XXXI, 1899, 232.

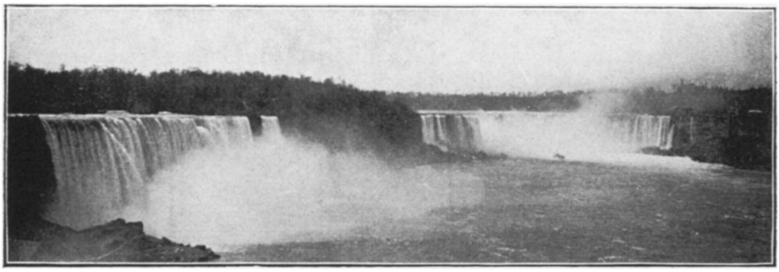

FIG. 7.—THE AMERICAN (ON THE LEFT) AND CANADIAN (ON RIGHT) FALLS.

EARLY VIEWS.—While Niagara was mentioned as early as the time of Champlain, it seems to have been first described from actual visit by Europeans by Father Hennepin,* whose account is interesting but unimportant and grossly exaggerated. Various other early travellers† described the Falls, but one of the best early

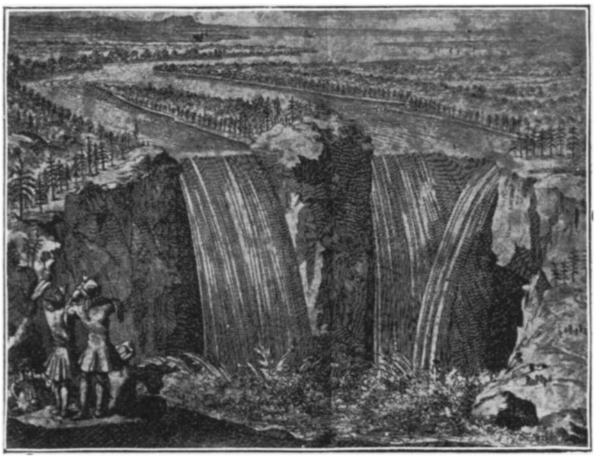

FIG. 8.—HENNEPIN'S PICTURE OF NIAGARA.

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* A New Discovery of A Vast Country in America, London, 1698, 24–6.

† See for instance, Dudley, Phil. Trans., VI, 1722, 69–72; Liancourt, Travels through the United States of North America, etc., in the Years 1795, 1796 and 1797, London, 1800, Vol. I, 390–394; John Mande, Visit to the Falls of Niagara in 1800,

accounts is that by Kalm.* While the first accounts are merely descriptive, more than 100 years ago there were speculations concerning the history of the cataract and gorge. We find, for instance, that Wm. Maclay,† in his journal for February 1, 1790, proposes to fix the age of the world by means of Niagara. He notes that the gorge is about seven miles long, and that the Falls have retreated some 20 feet in the 30 years since Sir Wm. Johnson visited them, making the age of the earth at least 55,440 years, a startling result for those times, as is shown by M'Causten's discussion of Niagara three years later.‡ He considers whether the Falls have really retreated and states that to have formed the gorge in the space of 5,700 years (the age of the earth) they must have gone much more rapidly than they appear to have done since he began to study them. In the same publication, Ellicott‖ announces his decision that Niagara has retreated through the seven miles of the gorge.

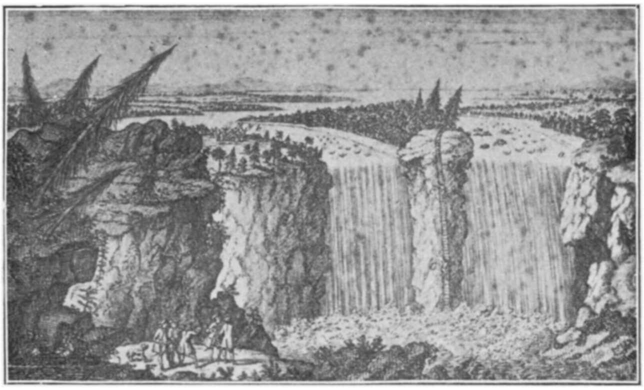

FIG. 9.—A VIEW OF NIAGARA FROM KALM'S PAPER.

In 1819 Atwater** assumes that Niagara has cut its gorge, thus

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London, 1826; Volney, View of the Climate and Soil of the United States of America (French edition, 1803), Philadelphia, 1804; Bigelow, Journal of a Tour to Niagara Falls, 1805, Boston, 1876; F. Hall, Travels in Canada, Boston, 1818, 230–240; Darby, A Tour from the City of New York to Detroit in the Michigan Territory, New York, 1819, p. 162; Schoolcraft, Narrative, Journal of Travels, etc., 1821, p. 33.

* Gentleman's Magazine, 1751, XXI, 15–19; another good account is by Weld, Travels through the States of North America, 1795, '96 and '97, London, 1799, pp. 308–323.

† Journal of Wm. Maclay, Appleton, New York, 1890, 190.

‡ Trans. Amer. Phil. Soc., 1793, 17–24; see also Eny's Visit to Niagara, 1787, Report on Canadian Archives, 1886, pp. CCXXVI–CCXXXIII, by Douglas Brymner.

‖ Trans. Amer. Phil. Soc., 1799, IV, 227–229.

** Amer. Journ. Sci., 1819, I, 116–125.

draining the lake that he believes once stretched over a part of Ohio. That this is not so is argued by Wells* and by Bourne.† In the same magazine Foot‡ states that the Falls were once at Lewiston. Eaton‖ gives the first geological section showing the structure at the Falls. Next comes an article by Geddes,** who argues against the conclusion that Niagara has carved its gorge.

The most important early work upon Niagara was that done by Capt. Basil Hall†† who went behind one of the smaller Falls, and noted the violent blasts of air caused by the falling spray, and pointed out its importance in undermining the Niagara limestone by removing the friable shales.‡‡ His description of the river is so excellent that I quote from it:

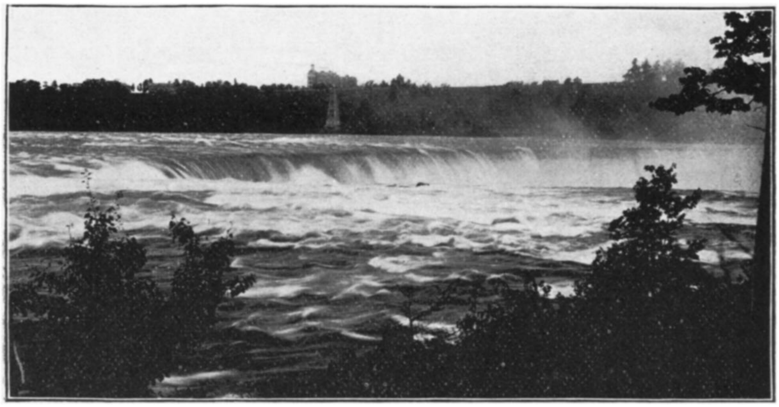

FIG. 10.—THE CREST OF THE HORSESHOE OR CANADIAN FALL.

> "The river Niagara which flows from Lake Erie into Lake Ontario, is unlike any other river that I know of. It is a full-grown stream at the first moment of its existence, and is no larger at its mouth than at its source. Its whole length is about thirty-two miles, one-half of which is above the Falls, and the other half lies between them and Lake Ontario. During the first part of its course, or that above the tremendous scene alluded to, this celebrated river slips quietly along out

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* Amer. Journ. Sci., 1819, I, 331–337.

† Amer. Journ. Sci., 1820, II, 30–34.

‡ Amer. Journ. Sci., 1822, IV, 35–37.

‖ Geological and Agricultural Survey of District Adjoining the Erie Canal, Pt. I, 1824, p. 149.

** Amer. Journ. Sci., 1826, XI, 213–218; Trans. Albany Inst., 1830, I, 55–59.

†† Amer. Journ. Sci., 1828, XIII, 364–368; Travels in North America, Vol. I, 1829, Edinburgh, 177–208; Forty Etchings made with the Camera Lucida in North America, in 1827 and 1828, Edinburgh, 1829.

‡‡ See also Mitchell, Observation on the Geology of North America (bound with Cuvier's Essay on the Theory of the Earth, New York, 1818), pp. 351-360.

of Lake Erie, nearly at the level of the surrounding flat country. So nearly so, indeed, that if by any of those chances which swell other rivers, but have no effect here, we could suppose the Niagara to rise perpendicularly eight or ten feet, the adjacent portion of Upper Canada on the west, and of the State of New York on the east, would be laid under water.

"After the river passes over the Falls, however, its character is immediately and completely changed. It then runs furiously along the bottom of a deep, wall-sided valley, or huge trench, which seems to have been cut into the horizontal strata of the limestone rock by the continued action of the stream during the lapse of ages. The cliffs on both sides are at most places nearly perpendicular, without any interval being left between the cliffs and the river, or any rounding of the edges at the top; and a rent would seem a more appropriate term than a valley. Above the Falls, therefore, that is, between them and Lake Erie, it will be understood, there is literally no valley at all; as the river flows with a gentle current, and almost flush, as seamen call it, or level with the banks;—while below the cataract, the bed of the river lies so deep in the earth, that a stranger, unprepared for these peculiarities, is not aware of there being any break at all in the ground, till he comes within a few yards of the very edge of the precipice. In point of fact we did drive for some distance on the American side of the valley or ravine of Niagara, across which we were looking, all the while, at the scenery in Canada, without knowing it, and without being in the least degree conscious that such a strong natural line of demarcation was interposed between us and that province."

He pointed out that the gorge is now being noticeably extended, giving instances of recent retreat, and argued that the gorge itself has been formed by this same slow work. This description of Basil Hall's marks the real beginning of the scientific study of Niagara, and its importance deserves full recognition.

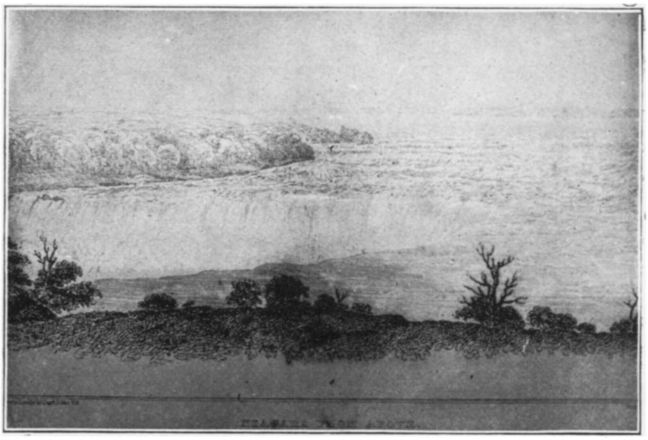

FIG. 11.—NIAGARA IN 1827, FROM A CAMERA LUCIDA DRAWING BY CAPT. BASIL HALL.

Henry* states that the Niagara gorge has been cut out by the irresistible current of the river. In the same year Bakewell[*] published his first discussion of Niagara, in which he points out that there has been a retreat of about 50 yards in 40 years, at which rate the age of the gorge is 9,856 years, though he states clearly that, owing to the variations in rock and in water supply, this estimate could not be considered accurate. Bakewell also recognizes the true cause for retreat previously so clearly stated by Capt. Hall.

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* Trans. Albany Inst., 1830, I, 101.

Conybeare, [†] however, opposes the view that Niagara has cut its gorge. Fairholme,[‡] on the other hand, accepted the idea of retreat and placed the rate at 4 feet a year; and, making various assumptions, considered the age of the gorge to be 4,500 years, placing the beginning at the Mosaic deluge. Rogers[§] points out the weakness of this argument and also opposes Bakewell's view, and questions whether the Falls were ever at Lewiston. Rogers notes the existence of fresh-water shells in the gravels of Goat Island, now accepted as evidence of the former greater height of the river when the Falls were standing further down stream than now.

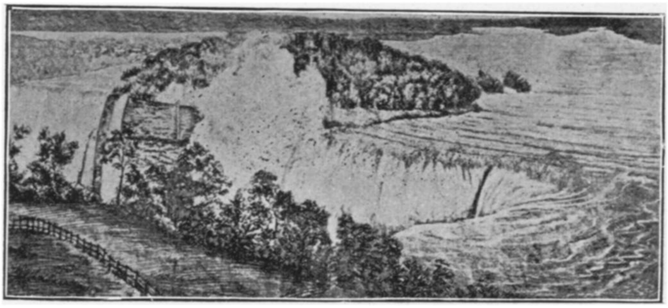

FIG. 12—NIAGARA IN 1832, FROM A CAMERA OBSCURA DRAWING BY RANSFORD.

Dr. James Hall [‖] states that the cataract was once at Lewiston and points out the fact that, since the strata which determine the Falls are dipping toward the south, that is up stream, the height of the Falls will diminish as they retreat up stream. In fact, when they have retreated two miles farther the shale beneath the limestone will have dipped so far below it that the Falls will then be located entirely upon the Niagara limestone, thus removing one of the chief causes for the present cataract. When that time arrives, the Falls will change to a series of rapids. The statement sometimes made that Niagara Falls will retreat until Erie is drained is therefore unfounded.

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[*] Mag. Nat. Hist., 1830, III, 117–130.

[†] Phil. Mag., 1831, IX, 266–267.

[‡] Phil. Mag., 1834, V, 3rd Ser., 11–25; See also Fairholme, New and Conclusive Physical Demonstrations both of the Fact and Period of the Mosaic Deluge, London, 1837; See also Gibson, Amer. Jour. Sci., 1836, XXIX, 201–213.

[§] Amer. Journ. Sci., 1835, XXVII, 326–335.

[‖] Second Rept. Geol. Survey of New York, 1838, 371–373.

The same author later* gives a very full description of Niagara, and a convincing argument in favor of the view that the Falls were once at Lewiston. However, with the clearness characteristic of his scientific mind, he recognized the importance of definitely determining the rate of retreat and for that purpose had made for future comparison an instrumental survey of the Falls which has been of the greatest service in later studies of the Falls.

Hall points out that the history of Niagara has not been uniform, but that the recession was probably at first rapid, the Niagara limestone being then much thinner than at the site of the present Falls. He shows, too, that when Niagara first began, there may very well have been three falls instead of one great cataract, one located upon the Niagara limestone, the other two on the still lower hard layers, which have now dipped out of sight far north of the crest of the present Falls.

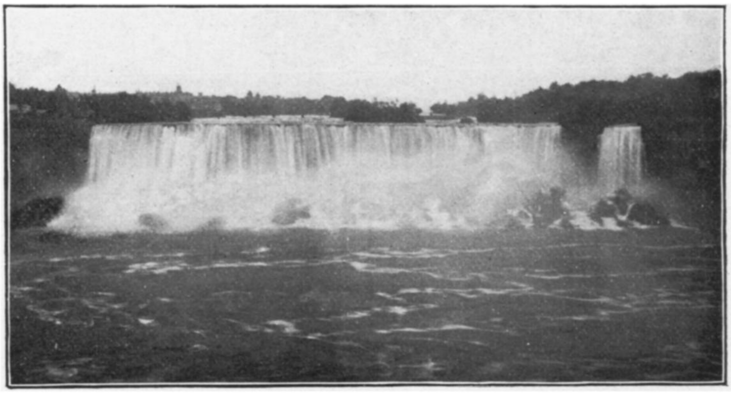

FIG. 13.—THE AMERICAN FALL, SHOWING THE LARGE BOULDERS WHICH ENCUMBER ITS BASE BECAUSE THE CATARACT HAS NOT POWER ENOUGH TO REMOVE THEM AS THEY FALL.

About this time there were a number of articles on Niagara containing little of importance. Hayes,† considering the lake beaches as marine, ascribed Niagara gorge to the scouring action of the high and powerful tides. Featherstonhaugh* affirms that Niagara has carved its gorge and shows the relation of the work to the hard and soft strata. Allen† states that 167,862,420 gallons of water, or 701,250 tons, pass over Niagara Falls every minute, representing 4,533,334 horse power.

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* Hall, Geol. Survey New York, Fourth Dist., 1843, 383–404; Reprinted in Eighth Rept. Niag. Comm. Rept., 1892, 67–89; Boston Journ. Nat. Hist., IV, 1843–44, 106–134.

† Amer. Journ. Sci., 1839, XXXV, 95–105.

Lyell's visit to America‡ included a study of Niagara, from which some important facts were added. He brings forward strong arguments in favor of the theory of retreat of the Falls, both present and past, and, assuming a rate of about one foot a year, reaches the conclusion that the gorge is about 35,000 years old. While assuming uniformity of retreat, he recognizes that there were causes which would prevent such uniformity, so that Niagara is not a good chronometer. He believed that the river flowed into the sea during the submergence of the land, as represented by the beaches, which he assigned to marine action. There were at first three falls, according to Lyell, and the river work has varied with the retreat of the Falls. He also recognizes that the Falls will in time be destroyed, as pointed out by Hall, when the cataract has retreated up stream about two miles further. One of the important arguments for retreat brought forward by Lyell is the presence of river gravels, not only at Goat Island, as previously recognized, but resting on the limestone cap of the gorge, four miles below the Falls, *proving* at least that much recession. He points out that all this has happened so recently that animals still existing were then living on the earth, and that if so recent an event has required so long a time, a vast period of time is required for the preceding geological events.

This description of Lyell's is one of the most important early contributions; but one of his most valuable results was the discovery, in company with Dr. Hall, of the drift-filled valley at the Whirlpool and the recognition of its connection with the break in the escarpment at St. David's.§ Since that time the Whirlpool-St. David's gorge has figured in the discussion of Niagara.

Bakewell‖ explains the St. David's channel as a valley excavated by water, then submerged and drift-filled. This valley the present

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* Proc. Brit. Assoc. Adv. Sci., 1844, 45–46.

† Amer. Journ. Sci., 1844, XLVI, 67–73.

‡ Travels in North America, 1845, Vol. I, 27–53; Vol. II, 90; also Eight Lectures on Geology, 1842, 43–47; Proc. Geol. Soc., London, IV; Amer. Journ. Sci., XLVI, 1844, 314–317; London Athenæum, 1842, No. 750; 1843, No. 796.

§ Vol. 2 of Travels, p. 90.

‖ Amer. Journ. Sci., LIV, 1847, 25–36.

Niagara encountered in its gorge-cutting and excavated rapidly, carving out a deep pit at the Whirlpool.

Agassiz[*] and Desor[†] wrote upon the Falls; and Gibbes,[‡] opposing Desor, advocates Hall's view of the origin of the gorge, stating that the slow rate of retreat at the American Fall does not properly serve as a basis for argument upon the question of *general* retreat, since at one time there was no American Fall. We now know that Gibbes was right, for the American Fall is retreating very much more slowly than the Horseshoe Fall. Hall,[§] commenting upon Gibbes' paper, agrees with him, and states that, at the present rate of difference in retreat, the Horseshoe Fall will in time entirely rob the weaker American Fall.

Bakewell[‖] in 1857, writes once more upon the subject and states that there has been a marked change in the Falls since he first visited the region in 1829. He clearly states the difference between the American and Horseshoe Falls in amount of work,[**] a difference earlier proposed by Gibbes, and argues that there is an immense pothole at the base of the Horseshoe Fall in which the fallen blocks of Niagara limestone are ground up, while the smaller volume at

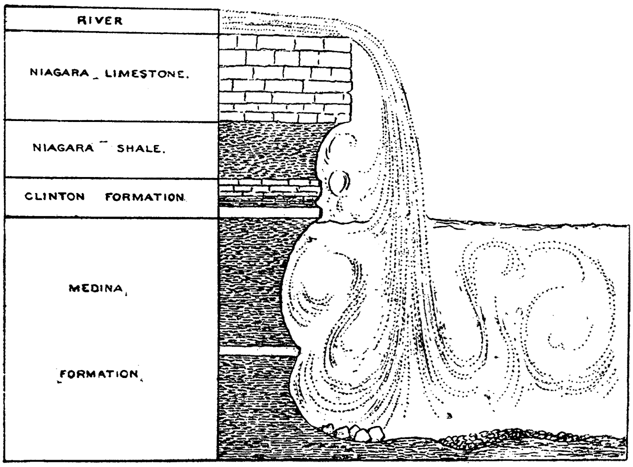

FIG. 14.—AN IDEALIZED SECTION OF NIAGARA (AFTER GILBERT).

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[*] Lake Superior, Boston, 1850, 15–16.

[†] Zeit. Geol. Gesell., 1853, V, 643–644.

[‡] Proc. Amer. Assoc. Adv. Sci., 1856, X, Part 2, 69–76.

[§] Proc. Amer. Assoc. Adv. Sci., 1856, X, Part 2, 76–78.

[‖] Amer. Journ. Sci., 1857, LXXIII, 85–95.

[**] See also, upon this point and others connected with Niagara, Marcou, Bull. Soc. Geol., France, 2nd Ser., XXII, 290–300, one of the important early studies.

the American Fall is unable to dispose of the fallen boulders, which therefore remain as a protection to the weaker rocks underneath the limestone.

The river gravels of Goat Island are mentioned by Ramsay;* and the Falls are described in popular articles by Hyatt† and Tyndall.‡ Holley criticizes the latter and states certain facts observed by him which lead him to the belief that the rate of retreat of the Falls is about 4 inches a year, making the age of the gorge 72,000 years.§ Belt also writes a popular article.‖

As a result of these studies, it may be stated that, while there was still much that was purely speculative, many of the major problems of Niagara were solved by them. It was proved beyond question, for instance, that a large part, and probably all, of the gorge had been cut out by the action of the river water. A number of persons contributed to this proof, the last important one being Lyell. Although estimates varied, a fairly close approximation to the rate of present retreat had been made, and the age of the gorge stated in figures, though in nearly every case with a clear recognition of the fact that there were causes which had operated to modify any estimate based upon the present rate.

The existence and significance of the Whirlpool-St. David's channel had been discovered and the relation of the Whirlpool to it noted. The rapidity of retreat of the Horseshoe Fall had been clearly recognized and the difference between it and the American Fall pointed out. It was also shown that, at the present rate, it was merely a question of time when the Canadian Fall would rob the American of its water and the two falls be replaced by one, which in time would change to a series of rapids, when, with the southward dip of the strata, the underlying shale had dipped down so far that the swirl of the cataract water could not reach it and remove it from beneath the Niagara limestone.

Many other facts had been stated and many logical conclusions had been drawn fully a quarter of a century ago. Indeed so much had been learned that it would have seemed as if little more were left to be done. But the publication of discussions has continued down to the very present, and it should be said that, as a result of these, we are now less certain of some things connected with Niagara than we were in 1880. It is chiefly as the result of the later studies of the Great Lakes that new facts have been discovered which apply to Niagara. This is particularly true of that part of the Niagara problem which relates to the *age* of its valley. For a while the gorge seemed to promise to serve as a geological chronometer of great importance; and from very early times this aspect of the Niagara problem has received marked attention. In later years this part of the question has been analyzed more carefully; and, because of its importance, we will now take it up specifically.

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* Quart. Journ. Geol. Soc., 1859, XV, 212–215.

† American Naturalist, 1869, II, 77–85.

‡ Popular Sci. Mon., 1873, III, 210–226; Macmillan Mag., 1873, XXVIII, 49–62.

§ Holley, Proc. Amer. Assoc. Adv. Sci., 1873, XXII, 147–155. See also Holley's Falls of Niagara, New York, 1883; Niagara, its History, Geology, etc., 12th ed., Toronto, 1872. See also Gunning, Popular Science Monthly, I, 1872, 564–573.

‖ Quart. Journ. Sci., 1875, XII, 135–136; See also Carpenter, Nature, 1881, XXIII, 511–514.

PRESENT RATE OF RETREAT.—In the first three-quarters of this century any estimate of the existing rate of retreat of Niagara Falls was necessarily based upon very meagre evidence and amounted to little more than a guess, as is shown by the wide variety of opinion expressed. By the wise foresight of Dr. James Hall,[*] the State

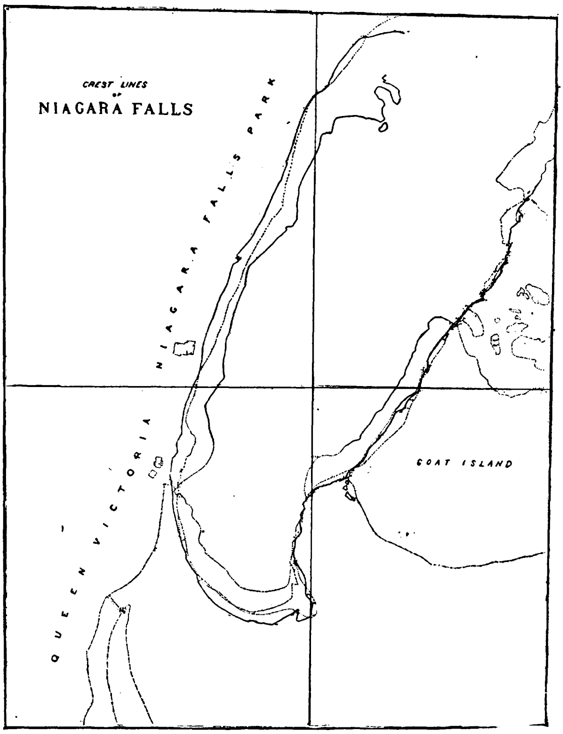

FIG. 15.—CREST LINES OF NIAGARA FALLS (AFTER KIBBE); OUTER LINE SURVEY OF 1842; SECOND LINE SURVEY OF 1875; THIRD LINE SURVEY OF 1886; FOURTH LINE SURVEY OF 1890.

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[*] Geol. of New York, 4th Dist., 1843, 402.

Geologist of New York, a map based upon an instrumental survey was made in 1842. In 1875 the Lake Survey, under the direction of Major C. B. Comstock of the Corps of Engineers of the U. S. Army, prepared its map of the Falls and gorge (Fig. 15). Wright makes use of these maps* to make an estimate of the rate of retreat, from which he places the age of the gorge at about 7,000 years, though he mentions the fact that there are elements of uncertainty in such a calculation because of probable variations from this rate. Wessor† gives the rate of retreat of the American Fall as 10 inches, and the Horseshoe Fall 3½ feet a year. This makes about 10,000 years as the age of the gorge, assuming a constant rate for the past.

A survey by Woodward in 1886‡ serves Gilbert§ with an opportunity of stating that the rate of recession in the central third of the Horseshoe Fall for 44 years was about 200 feet. With the same rate the age of the gorge must be calculated at about 7,000 years; but he points out many possible variables. Another survey was made in 1890,‖ by which it is shown that the average annual retreat in 48 years is .64 feet for the American Fall and 2.18 feet for the Horseshoe; but the rate of retreat in the central part of the Horseshoe Fall is much faster, and from this the rate of gorge formation is to be calculated.

CAUSES FOR PAST VARIATION IN RATE.—Gilbert has given the clearest and most complete statement for past variation in rate of gorge cutting,** as he has, in fact, upon the general question of Niagara River. He notes the following causes:—possible presence of preglacial or interglacial valleys coinciding with a part of the present valley, thus increasing the rate; a thinner limestone and a greater thickness of the under shales in the lower course, together with a former greater height of the fall, all of which tend to increase the rate; a narrower channel in places, which has called for less work; the probable presence of floating ice to help in the excavation; and, finally, possible variations in detrital load, in the chemical composition of the water and in its *volume*.

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* Science, 1885, V. 399–401.

† Nature, XXXII, 1885, 229–30. See also a brief note by Garbett in same, 244–245.

‡ Science, 1886, VIII, 205.

§ Proc. Amer. Assoc. Adv. Sci., 1886, XXXV, 222–3; Science, 1886, VIII, 205; See also Gilbert, Nature, L, 1894, 53; also Kingsmill, same, 388.

‖ Kibbe, Seventh Rept. Niag. Reserve Comm., 1891, 96–102; Woodward, 103–116.

** Proc. Amer. Assoc. Adv. Sci., 1886, XXXV, 222–3; Science, 1886, VIII, 205.

The latter point has been elaborated by Spencer* and by others. Spencer shows that when the land was lower in the north† the waters of the Great Lakes were diverted from Niagara, which then contained only a small stream. He believes that the early Falls were somewhat like the present, and that these were followed by three falls, as at present in the Genesee. The life of the river is divided into episodes, each of which is estimated, giving the total life of the river 32,000 years and of the gorge 31,000 years.

The view of the variation in volume of water previously suggested by Gilbert (see p. 331), and definitely advanced by Spencer, is accepted by Gilbert in later articles.‡ But it is to Taylor that we owe the latest and most thorough study of the ancient outflows

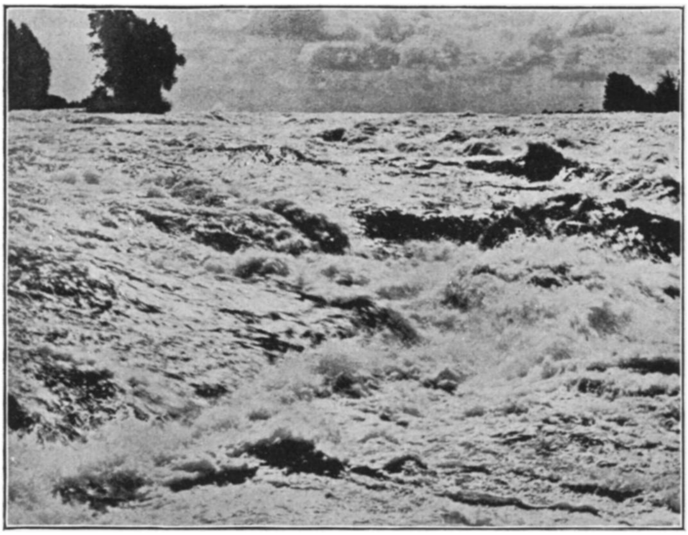

FIG. 16.—THE RAPIDS ABOVE THE FALLS.

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* Proc. Amer. Assoc. Adv. Sci., 1888, XXXVII, 197–199; Trans. Roy. Soc. Canada, 1889, VII, Sect. IV, 121–134; Proc. Amer. Assoc. Adv. Sci., 1894, XLIII, 244–246; Amer. Journ. Sci., 1894, CXLVIII, 455–472; Amer. Nat., 1894, XXVIII, 859; Amer. Geol, 1894, XIV, 298–301; Proc. Roy. Soc., 1894, LVI, 145–148; Pop. Sci. Monthly, XLIX, 1896, 157–172; Amer. Geol. 1898, XXI, 110–123; Amer. Journ. Sci., CLVI, 1898, 439–450. A number of Spencer's papers are reprinted in 11th Rept. Niag. Comm., 1895, App., pp. 1–126. For references to other papers by Spencer see Tarr, Bull. Amer. Geog. Soc., 1899, XXXI, 221.

† Spencer, Am. Journ. Sci., CXLVIII, 1894, 455–472.

‡ Sixth Rept. Niagara Com., 1890, 61–84; Same Rept. Internat. Cong. Geol. 5th Session, Washington, 1891 (Pub. 1893), 455–458; Physiography of United States, New York, 1896, 203–236.

of the Great Lakes, by which Niagara has been temporarily robbed of its water;* and he has naturally made application of these studies to the Niagara problem.†

Taylor's conclusions concerning the influence of variation in water supply on the age of the Niagara gorge may be briefly summarized as follows: In the first place, he shows how variable are the width and depth of the gorge in different parts. There is first an *upper great gorge* extending from the base of the Falls nearly to the railway bridges, being broad and deep. This is followed by the second section of the gorge, the *Whirlpool Rapids*, shallow and narrow, and this by the third section, the *middle great gorge*, which includes the Whirlpool and extends below it. Here the width is about that of the upper great gorge and the depth is considerable.

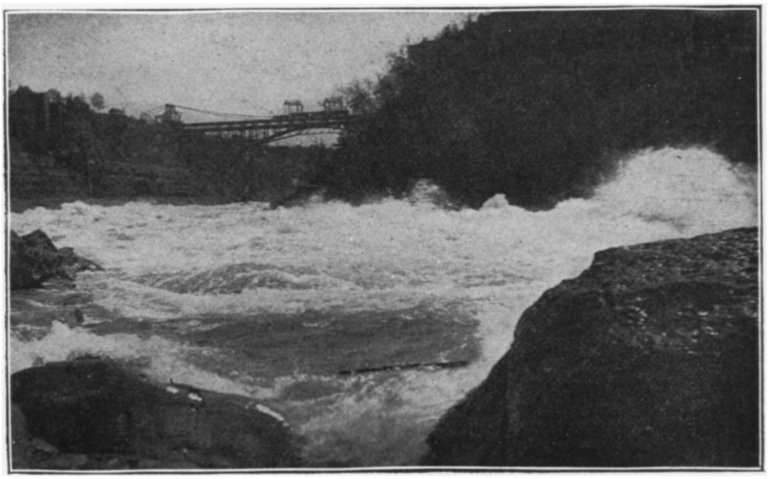

FIG. 17.—THE WHIRLPOOL RAPIDS.

This is followed by the fourth section, the *lower gorge*, which is prevailingly narrow and rather shallow, for the most part.

Taylor thinks that the upper broad gorge may be the part that has been formed since the Nipissing outflow was abandoned; and, at the present rate of cutting, this portion of the gorge has required about 2,700 years. The Whirlpool Rapids section is believed to have been formed by the river when it was so small that the Niagara limestone boulders were not removed, the fall at that time being similar to the present American Fall in mode of work. At this rate of cutting, the Whirlpool Rapids section must have required several thousand years, the amount not being definitely estimated by Taylor. The section below this must have been formed when the volume of Niagara was large, just before the time of the Nipissing overflow.

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* See Tarr, Bull. Amer. Geog. Soc., XXXI, 1899, 35.

† Taylor, Amer. Journ. Sci., CXLIX, 69–71; 249–270; Amer. Geol., 1895, XV, 100–120, 162–179; Amer. Geol., 1896, XVIII, 108–120; Amer. Journ. Sci., 1897, CLIII, 208–218; Studies in Indiana Geography, Terre Haute, 1897, 109–110; Amer. Geol., 1897, XX, 65–66; 111–128; Proc. Amer. Assoc. Adv. Sci., 1897, XLVI, 201–202; Bull. Geol. Soc. Amer., 1898, IX, 59–84. See particularly last paper.

No attempt is made to analyze the paper and to state the facts which Taylor brings forward in support of this hypothesis. Without a very much longer abstract than is possible here, justice could not be done to the paper, and it is necessary to refer to the publication itself, if the reader wishes to follow Taylor's argument in detail. It is an exceedingly brilliant piece of work, and calls for very careful consideration on the part of students of the Niagara problem.

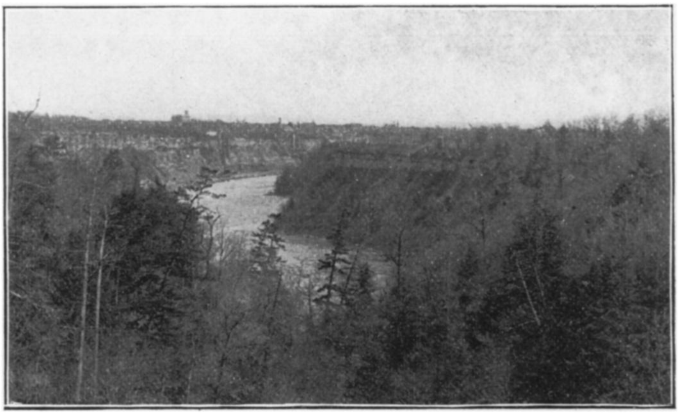

FIG. 18.—THE NIAGARA GORGE.

The outflow over the Nipissing Pass, through which the waters of the Great Lakes passed to rob Niagara of its volume, has also been studied by Wright;* but he does not agree with Taylor in the assumption of long overflow over this Pass, upon which Taylor bases much of his argument for the great age of Niagara gorge.† Upham‡ has taken a vigorous stand against the long occupancy of this overflow of the Great Lakes, as maintained by Taylor. So it will be seen that the somewhat startling conclusion reached by Taylor that the Niagara gorge is not less than 30–50,000 years old is based upon an interpretation of the facts to which all do not agree.

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* Bull. Geol. Soc. Amer., 1893, IV, 423–425. See Bell's comment on this, pp. 425–427.

† Amer. Geol., 1898, XXII, 260–261; Science, 1898, VIII, 502.

‡ 22nd Rept. Minnesota Geol. Survey, 1894, 54–66; Nature, 1894, L, 198–199; Amer. Geol., 1894, XIV, 62–65 (Spencer's reply to this pp. 135–136); 23rd Rept. Minn. Survey, 1895, 156–193; Bull. Geol. Soc. Amer., 1895, VI, 21–27; Amer. Journ. Sci., 1895, CXLIX, 1–18; Amer. Geol., 1896, XVIII, 169–177.

Another possible cause for the variation in rate of excavation of the Niagara gorge is the drift-filled gorge of the St. David's-Whirlpool channel, first discovered by Lyell and Hall. This valley seems to represent a broad gorge cut into the rock to a level below the present water surface of the Niagara River at the Whirlpool. When this gorge was formed is not certain; but its time of development was evidently before the last advance of the glacier which clogged it with drift. Some ascribe it to interglacial, some to preglacial stream cutting; but so far as the Niagara problem is concerned the exact *origin* of the gorge is of little importance.

The question immediately concerning us is how far this gorge reached. Pohlman* believes that it represents the down-stream extension of the ancient Tonawanda Creek and that the gorge portion of this stream, now partly buried, really extended up the course of the Niagara as far as the railway bridges. Joining this, according to Pohlman, was a tributary from the northeast, also along the present course of the Niagara, having its source below the Whirlpool. The post-glacial Niagara encountered these interglacial or preglacial gorges, and quickly cleared them out, so that a very considerable portion of the present gorge was formed before the present Niagara was born, and was cleared of its drift-filling much more rapidly than the present rate of retreat of the Horseshoe Fall. According to Pohlman's argument, the age of the Niagara gorge, that is the length of the post-glacial time, is about 3,000 years.

No one appears to have accepted Pohlman's argument in full, though some have followed it in part. Spencer † argues against the theory that the gorge extended up stream, as Pohlman suggested. Indeed, in his later papers‡ he accepts the evidence presented by Claypole, and concludes§ that there is rock extending across the supposed preglacial gorge, and hence that it was not a continuous stream course from the Whirlpool to St. David's, but a tributary to preglacial Tonawanda Creek. Gilbert,* however, says that the St. David's-Whirlpool gorge is a well-defined, filled channel, and not rock interrupted. He thinks that it extended up the present course of Niagara for a distance of 200 or 300 yards, and perhaps even further than this. Wright† believes that the buried gorge was made by a small preglacial stream, and that the age of Niagara gorge is from 10,000 to 12,000 years. Upham ‡ believes that the buried gorge extended up stream along the present course of Niagara, and explains the narrowness of the Whirlpool Rapids section on this basis. He estimates the age of the gorge at from 5,000 to 10,000 years. Just the opposite conclusion is reached by Taylor,§ who ascribes the buried gorge to the action of a cataract that had just reached to the southern side of the Whirlpool basin when the glacier advanced to stop its work.‖ His estimate of the age is 50,000 years, or perhaps less.

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* Proc. Amer. Assoc. Adv. Sci., 1883, XXXII, 202; Same, 1886, XXXV, 221–222; Trans. Amer. Inst. Mining Eng., 1889, XVII, 322–338.

† Amer. Nat., 1887, XXI, 269–270.

‡ Spencer, Proc. Amer. Assoc. Adv. Sci., 1894, XLIII, 244–246; Amer. Journ. Sci., 1894, CXLVIII, 455–472; Amer. Geol., 1894, XIV, 298–301.

§ Science, 1886, VIII, 246. See papers by Scovell announcing the discovery of a buried channel near Niagara, Amer. Geol., 1889, III, 195–196; Proc. Amer. Assoc. Adv. Sci., 1890, XXXIX, 245–246.

From this maze of conflicting estimates, it is impossible at present to reach a definite conclusion. The best I can do is to state what seems to me to be the present status of the problem of the post-glacial history of the gorge.

In the early post-glacial stages of the river, its course extended five miles beyond the present mouth, as shown by Gilbert.** This lowered the base-level of the river so that it was enabled to cut a deeper channel than was later possible.†† At first the fall was not vertical, being made over the north-sloping escarpment; but it speedily changed, probably to a series of three falls, as argued by Hall (p. 326), or possibly to a torrential rapid, dependent upon the thinness of the Niagara limestone at the lower end of the gorge. Above Foster Flats, as suggested by Pohlman, the river may have encountered a buried tributary to the St. David's-Whirlpool gorge; or the drift-filled valley may not have been reached until the river had cut back to the northern edge of the Whirlpool. At whichever place this buried valley was first encountered, the fall abruptly changed to a rapid stream, which quickly cleared out the buried gorge as far as it extended, and then assumed the form of the present cataract. During this time the volume of water changed as the outflow of the upper Great Lakes varied in position, as has been stated by Gilbert, Spencer, Wright and Taylor.*

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* Amer. Geol., 1896, XVIII, 232.

† Amer. Jour. Sci., 1884, CXXVIII, 32-35.

‡ Bull. Geol. Soc. Amer., 1898, IX, 101-110.

§ Bull. Geol. Soc. Amer., 1898, IX, 56-84.

‖ See also Davis, Amer. Journ. Sci., 1886, CXXXII, 323; also Davis, Johnson's Cyclopedia, 1895, article on Niagara, Consideration of the Problem.

** Sixth Rept. Niagara Comm., 1890, 61-84.

†† Upham, Bull. Geol. Soc. Amer., 1898, IX, 101-110.

The ingenious argument formulated by Taylor,† correlating the narrow and broad parts of the gorge with the variations in water volume, has many facts in its support; but it must certainly be held for the present as no more than an alternative view of the Niagara gorge history. I feel by no means certain that his conclusions are necessary. The narrowness and shallowness of the Whirlpool Rapids section of Niagara may be easily explained by Pohlman's theory. If the St. David's-Whirlpool gorge was formed by a stream of moderate size, its width would not have been great, especially near the head of the gorge; and with the small volume of water available, the nature of the work done by the preglacial fall would have been rather like that of the present American than the Horseshoe Fall. The gorge bed would then have been littered with massive limestone boulders, as the bed of the Whirlpool Rapids evidently is at present. Above this section, that is from the railway bridges to the present cataract, the work, having been done by a great volume of water acting as the present Horseshoe Fall does, would be represented by a great depth of cutting.

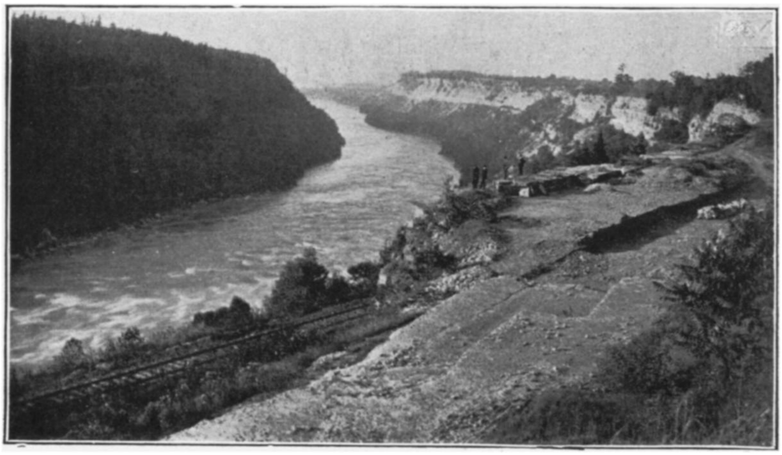

FIG. 19.—THE GORGE OF NIAGARA, WITH THE CAPPING OF NIAGARA LIMESTONE PLAINL. SHOWN ON THE RIGHT.

From all the facts that have been put forward, it would be at least as reasonable to explain the Whirlpool Rapids channel in this way as by Taylor's explanation,—namely, by a contracted Niagara during the time when the upper Great Lakes were flowing through another channel. The ledge of sandstone rock mentioned by Taylor as existing just above the Whirlpool, on which he bases a part of his argument, may well represent a waterfall, over which the water of the preglacial or interglacial river flowed, as has been suggested by Pohlman.* It has been said that this explanation is at least as satisfactory as Taylor's; it may be claimed that it is somewhat more satisfactory, since it tells why the Niagara River turns sharply at right angles at the Whirlpool.

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* See references (pp. 332–334).

† Bull. Geol. Soc. Amer., 1898, IX, 56–84; see also p. 333 of this article.

With regard to the variation in the width and depth of the lower gorge, it is more difficult to find an alternate explanation to that proposed by Taylor. It seems possible, however, that preglacial stream valleys, together with variation in the mode of action of Niagara, might explain this variation. What effect the change from a section of rapids to a series of three falls, and then to a cataract, might have upon the width and depth of the river valley, is not yet well enough known to warrant overlooking this as a possible explanation of the variation. Taylor's explanation is certainly a remarkable one, especially with respect to the close coincidence of alternations of broad and narrow gorges with the known alternation of large and small volume of water.

While the discussion by Taylor is a brilliant one and has many points in its favor, I find myself unable to accept his conclusions, partly because they do not seem necessary, and partly because they lead to a startling conclusion, which is quite at variance with other evidence.

In the first place, if the age of Niagara gorge is from 30,000 to 50,000 years, as the studies of Taylor and Spencer seem to indicate, the lower end of the gorge is from 30,000 to 50,000 years older than the upper. Yet no very noticeable difference in effect of weathering on the two ends can be found.† It would seem that such a long time must have permitted considerable effect of weathering, especially as the rate in recent years is known to have been noticeable in the lower part of the gorge near the railway line.

Moreover, before Niagara was born, beaches, terraces, eskers and drumlins were laid down as the direct or indirect result of the presence of the glacier, and these are now so fresh and undestroyed that they might be no more than 1,000 years old. Tiny stream channels on deltas are still preserved, and many other delicate forms of sculpturing testify to the youth of the deposits. If 30,000 years of exposure to denudation is not sufficient to noticeably modify such delicate land forms, surely the geologists must call for vastly greater periods of time than they are in the habit of calling for to account for the planing down of mountains over and over again. Such a conclusion as that of Taylor seems quite out of harmony with what we are accustomed to believe concerning the rate of denudation.

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* Proc. Amer. Assoc. Adv. Sci., 1886, XXXV, 221–222; Trans. Am. Inst. Mining Engineers, 1889, XVII, 322–338.

† Wright, Science, 1898, VIII, 502; Amer. Geol., 1898, XXII, 260–61; Proc. Amer. Assoc. Adv. Sci., 1898, XLVII, 299–300; Popular Sci. Monthly, 1899, LV, 145–154. See also Wright, Bull. Essex Inst., 1881, XIII, 71; Upham, Bull. Geol. Soc. Amer., 1898, IX, 101–110.

It has been pointed out by Hansen * that thirty independent estimates of post-glacial time, based upon different data, give results of between 5,000 and 12,000 years,† so that on the basis of probability the age of Niagara gorge should be somewhere between 7,000 and 10,000 years.

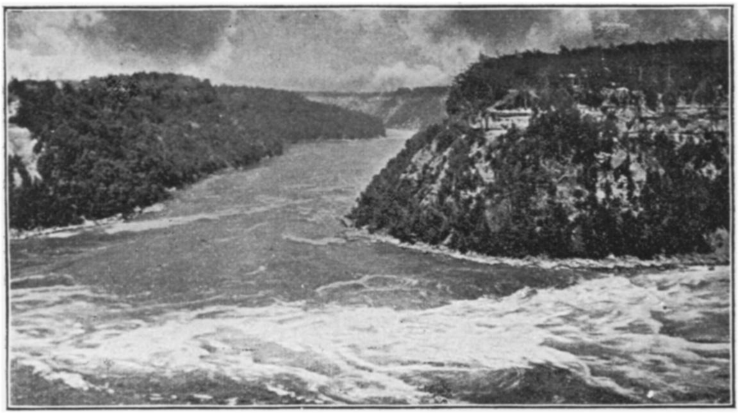

FIG. 20.—THE OUTLET OF THE WHIRLPOOL, WHERE THE RIVER BENDS SHARPLY.

Gilbert says ‡ that the problem of the age of Niagara cannot "be solved by a few figures on a slate, nor yet by the writing of many essays." To this every one who has given attention to the problem must assent. The longer the study, the more complex the

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* Journ. of Geol., 1894, II, 142.

† Upon this subject, see Winchell's discussion of St. Anthony Falls, Fifth Ann. Rept. Minnesota Geological Survey, 156–189; Quart. Journ. Geol. Soc., 1878, XXXIV, 886–901; Final Rept. Minnesota Survey, Vol. II, 1888, 313–341.

‡ Sixth Ann. Rept. Niagara Comm., 1890, 83.

problem appears, and we are bound to conclude that Niagara is not a good chronometer. Until more evidence has been obtained concerning the length of the overflow at Nipissing Pass, which some believe to have been long, others short, we are bound to remain in doubt whether the age is from 5,000 to 10,000 years or from 30,000 to 50,000 years.

The present rate is fairly well known; the former rate was less, for a time, when the volume of water was diminished; but the question of how long this diminution lasted cannot be answered with positiveness. While this factor would lengthen the time to an amount which cannot be definitely stated, it is worth while to note that nearly all the other important factors for variation would tend to shorten it by increasing the rate. Among these factors the more important ones are as follows: We know that the limestone in the lower part of the gorge is thinner than at the present cataract, and it seems certain that, as a result of this, the rate of cutting was once greater. At that time the height of the fall was greater and the shales beneath were thicker and hence more easily removed. At the same time it is to be noted that the mode of gorge formation was then different from the present, for there were probably three falls instead of a single one. In places the gorge is narrower than the one at present forming, so that less material had to be removed. Moreover, it seems certain that a part, and possibly a considerable part, of the present gorge was excavated before the *present* Niagara began its work.

When the ice sheet was withdrawing there must for a while have been a heavier rainfall, because of the neighborhood of the cold ice wall, which chilled the damp air from the south, doubtless rendered more damp than now because of the large amount of water near the front of and flowing away from the glacier. This rainfall must then have flowed off more freely and carried with it more sediment than at present, because, when the ice first withdrew, there was no forest cover to the land and at first no coating of vegetation whatsoever. There is evidence in many of the gorges of the Finger Lakes of central New York that this was so, and that the rate of work done in the early stages of the gorge formation was very much greater than it has been since the streams became diminished to their present volume. In these stream valleys there are usually two gorges, one broad, the other, inner one, narrow.

While it is certain that we must keep in mind the argument brought forward by Taylor and hold it as a working hypothesis, we must admit that the Niagara problem is by no means solved. My own interpretation of the evidence, as it at present stands, is that the indications are rather more strongly in favor of the theory that the gorge has required less than 10,000 years for its formation than toward the estimate of 30,000 to 50,000 years. The basis for the latter is too uncertain for its acceptance at present, particularly in the face of the difficulties which it brings forward. There is work yet to be done on the Niagara problem.

FOSTER FLATS.*—The rather remarkable projection of the side of the gorge at Foster Flats, just below the Whirlpool on the Canadian side, is worthy of special study. At this point is a projecting platform of Niagara limestone forming the land known as Wintergreen Flat. This represents an old river bed swept clear of drift by the current. Between this water-swept limestone platform and the electric car track there is a bluff of drift which represents one of the old river banks.

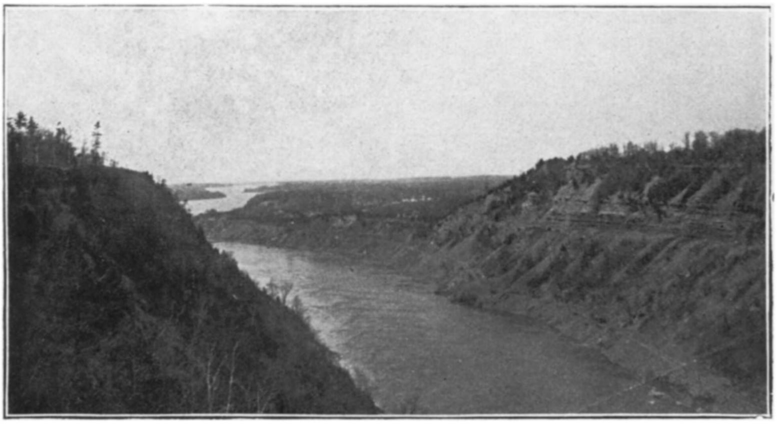

FIG. 21.—THE END OF THE NIAGARA GORGE AND THE LOWER PLAIN.

Standing on the northern edge of this platform one sees at his feet, at the base of a precipitous wall, a north-sloping valley littered with huge blocks of Niagara limestone, and bounded on the west, or left, by the normal gorge wall, on the right by a low ridge, strewn with loose blocks of the limestone.

Gilbert's explanation of these facts is that, at this point there existed, in the course of the Niagara, a small island which separated the cataract into two unequal parts, much as the larger Goat Island now divides the Falls, though with this exception, that the Canadian

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* Gilbert, Physiography of the United States, New York, 1896, 220.

Fall was then the smaller. The larger American Fall of these ancient times naturally retreated more rapidly than the smaller Canadian, and soon caused a withdrawal of the water from the Canadian side. This smaller fall had swept clear the channel and rock platform just described, and existed as a fall somewhat like the present American Fall. For a while after this stage the small Canadian cataract fell eastward over the edge of Wintergreen Flat, and then the larger fall on the American side entirely withdrew its water. The ancient Canadian Fall, like the present American, having been unable to remove the boulders from its foot by grinding them together, has left them there as one of the silent witnesses of the former existence of the falls. The narrow island, which was responsible for the division of the river, was so small that it was not able to withstand the later attacks of the water and weather and has almost entirely disappeared, being marked at present only by a low ridge separating the present river from the abandoned channel. This region of Wintergreen and Foster Flats is one of the most interesting in the whole course of Niagara River and well worth a visit by tourists, not alone for its scientific interest, but also because of its scenic beauty Notwithstanding this, not one in five hundred visitors ever stop off to see it.

FUTURE OF NIAGARA.*—Already the question of the rapid change in the form of Niagara Falls has been briefly considered. Upon the assumption that the conditions at present in existence are to continue, it seems evident that in time the American Fall will be robbed by the Canadian, and that there will be another dry platform where now the water rushes to the brink of the smaller fall. Moreover, when the cataract retreats up stream and reaches a region where the limestone becomes much thicker, its rate of retreat will decrease; and, finally, when the shales have dipped far enough into the earth to have practically disappeared from the reach of the water, the cataract will probably change to a series of rapids, while Niagara Falls will disappear.

But there may be some interference with this normal future. Leaving out of the question what man may do, it is by no means impossible that the water of Niagara may be entirely withdrawn from the present river. There is evidence enough that the level of the land is very unstable, and that this very instability has previously caused the withdrawal of the water from the Niagara channel by opening a lower outlet for the Great Lakes.

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*See Hallett, Geol. Mag., Decade III, 1, 563–564.

Spencer* brings forward evidence that the region near the Niagara River has been recently changed in level, and concludes that there is an uplift still in progress at the rate of about 1¼ feet a century. If this rate should continue in the future, as Spencer believes it has for the past 1,500 years, the Great Lakes will discharge into the Mississippi past Chicago in about 5,000 years from now. Gilbert † has more recently reached a similar conclusion. As the result of a very delicately made survey, he finds that there has apparently been a change in level in the time since certain bench marks were located near the shores of the Great Lakes. This recent change amounts to 6 inches a century at Duluth, 9 inches at Toledo, and 9 to 10 inches at Chicago. If this rate of uplift continues, the waters of the Great Lakes will begin to spill over the rim at Chicago in from 500 to 600 years from now, and in 3,500 years Niagara will be dry. To this prediction, however, one cannot attach any more weight than to the numerous estimates of the length of time occupied in the formation of the gorge. The future of Niagara, as well as its past, is wrapped in uncertainty.

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*Amer. Journ. Sci., 1894, CXLVII, 207–212; Proc. Amer. Asso. Adv. Sci., 1894, XLIII, 244–246; Amer. Geol., 1894, XIV, 298–301; Amer. Journ. Sci., 1894, CLVIII, 455–472.

†Nat. Geog. Mag., 1897, VIII, 233–247; Eighteenth Annual Report U. S. Geol. Survey, 595–647. See abstract of this in Bull. Amer. Geog. Soc., XXXI, 1899, 156.

NOTE.—It is not pretended that this bibliography is complete. A number of references (as to Belt, Bigsby, etc.,) which I have had, were in volumes not accessible to me; others were omitted to save space. A bibliography of Niagara, especially the popular accounts, will be found in the Tenth Report of the Niagara Commission, 1894, pp. 72–107, and also in Eleventh Report, 75–84. In most of the geological text books, as those by Dana, Geikie, Le Conte, Winchell, and others, Niagara is at least mentioned. See also the earlier text books, as Bakewell, Introduction to Geology; De la Beche, Geological Manual, and Lyell's Principles of Geology.